MIDAS: An Agent Based Data Transcoding Services Framework

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Data Preparation/Preprocessing

- Important step before analysis or mining
- Several preprocessing steps are general
  - Subsetting
  - Data Format Translation
  - Reprojection
- Subsetting: a data reduction step that helps in making the size of the data managable
- Data Format Translation: a format conversion step that allows the data to be stored in a familiar format

Project Objective

- To provide an *intelligent, automated data preprocessing* for Earth Science data

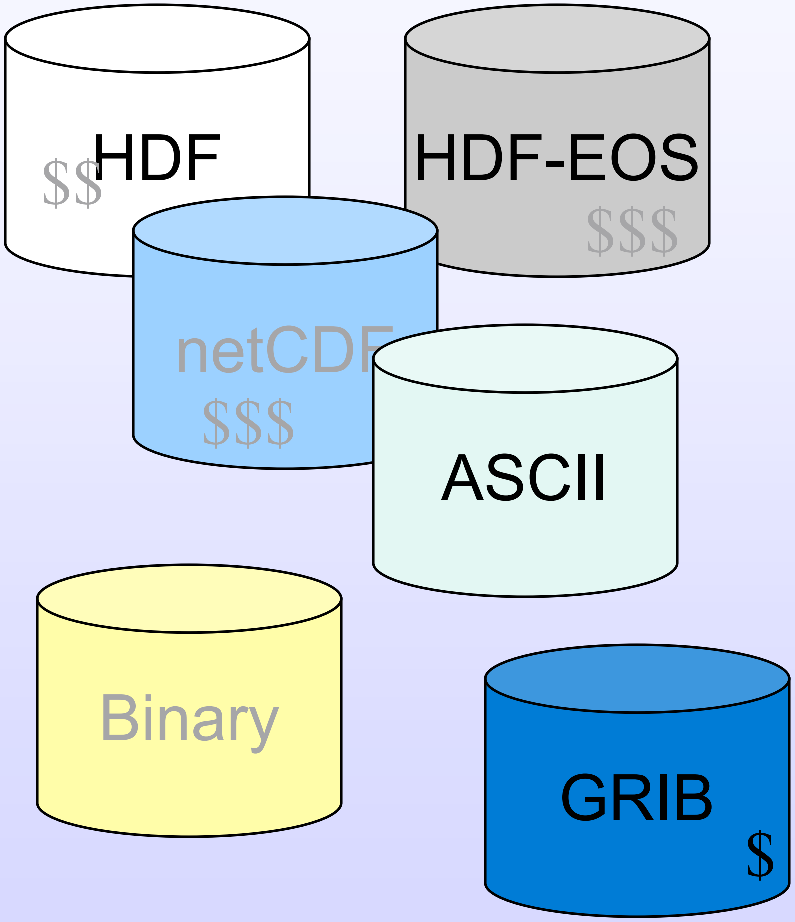
Challenges

- Requires a rich set of metadata
  - Structural metadata: to provide full description of the data file in bits & bytes, to allow application to read the data
  - Semantic metadata: to provide meaning of the data along with a context, to allow application to understand what it has read and how to use it
- Requires a Data Preprocessing Framework
  - Framework properties: Loosely coupled, asynchronous, intelligent and distributed

Metadata Solution

- Use Earth Science Markup Language (ESML) for structural metadata description
- Enhance ESML description by providing semantic metadata by leveraging ontologies

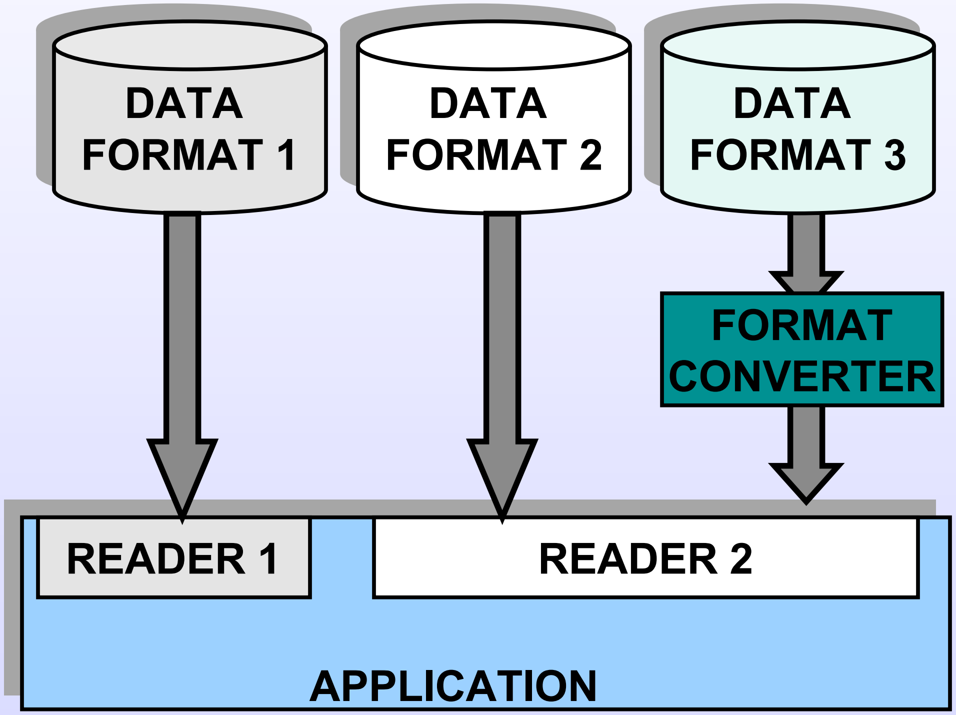
Background:
Earth Science Data Characteristics



- Different formats, types and structures (18 and counting for Atmospheric Science alone!)
- Some formats lack metadata where as others are metadata rich ($)

- **Heterogeneity leads to Data usability problem**

Background:
Data Usability Problem



- Requires specialized code for every format
  - Difficult to assimilate new data types
  - Makes applications tightly coupled to data
- One possible solution - enforce a Standard Data Format
  - Not practical for legacy datasets

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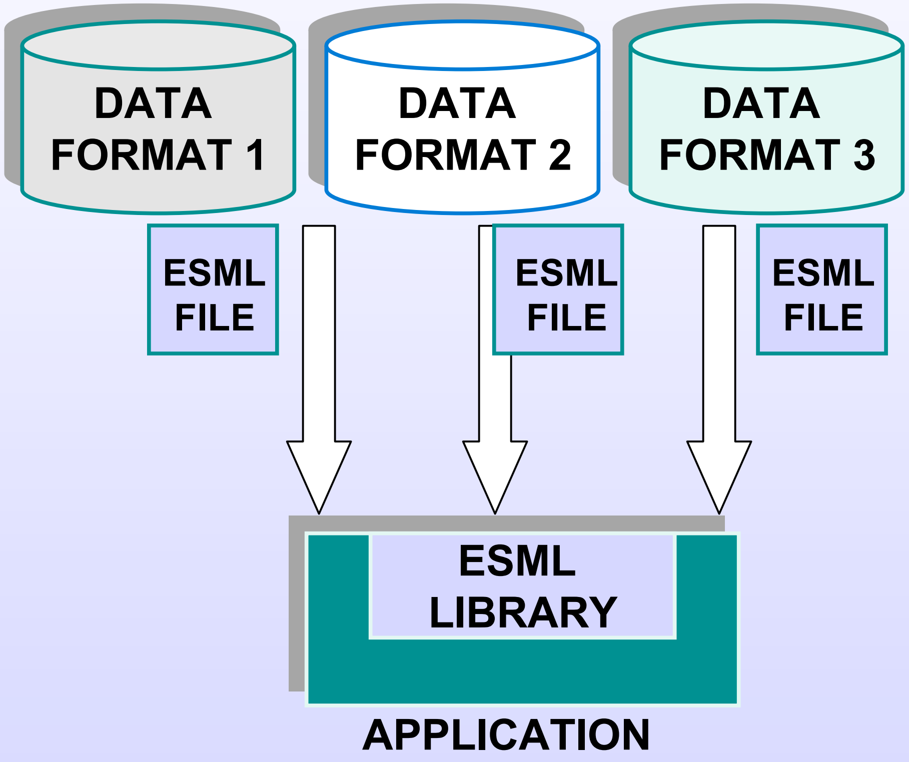
Background:
Earth Science Markup Language (ESML)



- ESML (external metadata) files containing the structural description of the data format
- Applications utilize these descriptions to figure out how to read the data files resulting in data interoperability for applications

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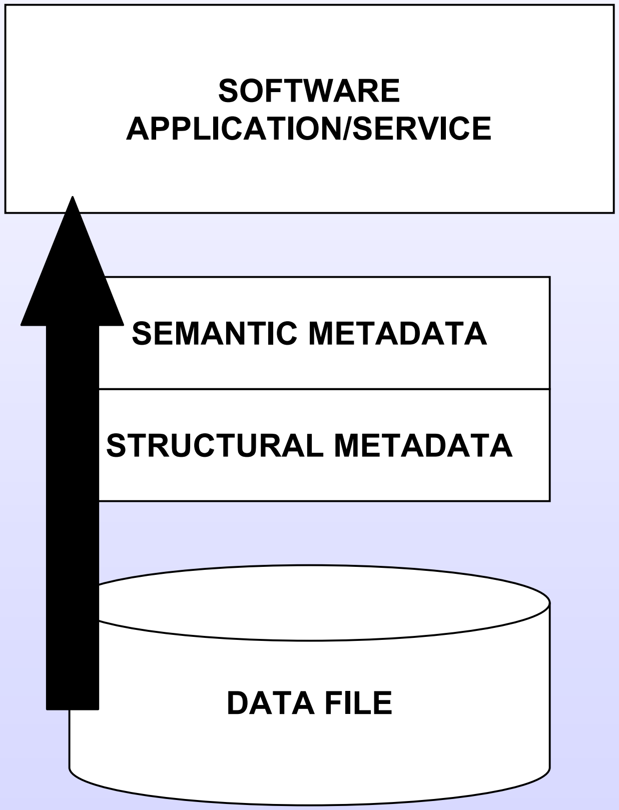
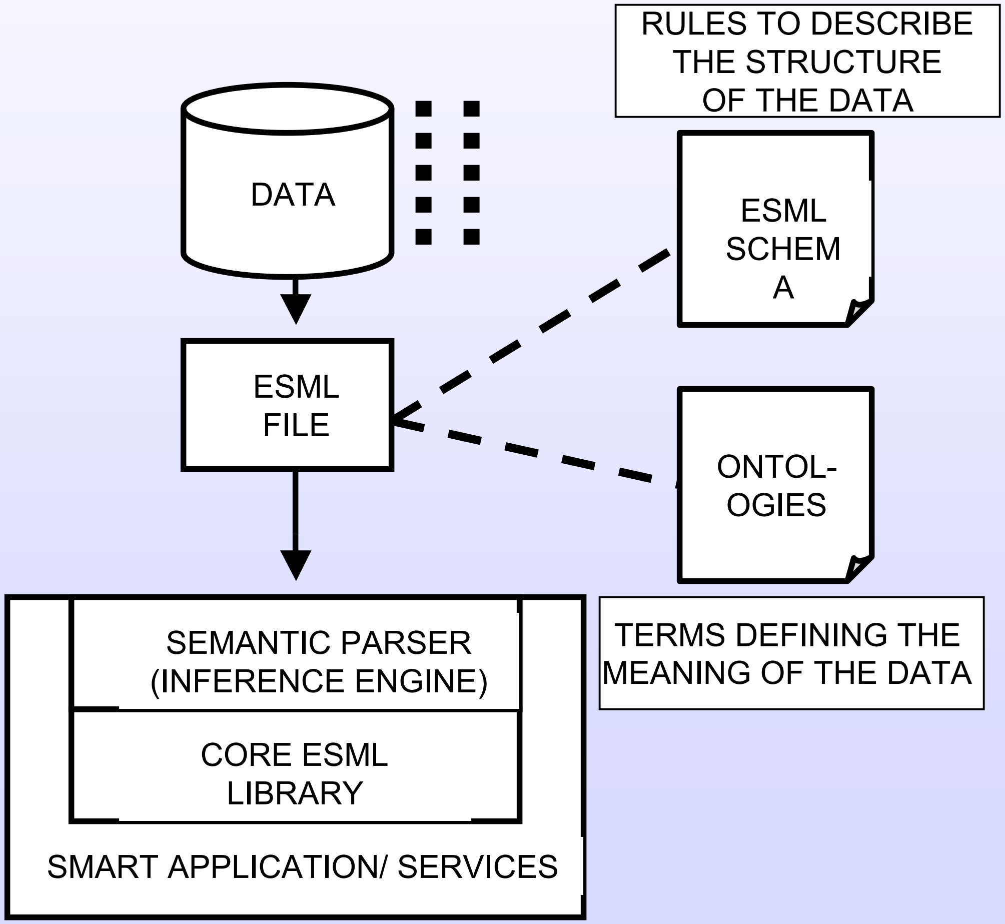
Requirement: Vertical Metadata Integration



- Horizontal Metadata Integration
  - Mediation services
  - Yellow page services
- Vertical Metadata Integration focuses on semantics for the use of the data by an application
- Both Structural and Semantic metadata are required

Solution:
Extending ESML with Ontologies


RULES TO DESCRIBE THE STRUCTURE OF THE DATA
DATA
ESML SCHEM A
ESML FILE
ONTOL- OGIES
SEMANTIC PARSER (INFERENCE ENGINE)
CORE ESML LIBRARY
SMART APPLICATION/ SERVICES
TERMS DEFINING THE MEANING OF THE DATA

- ESML Schema provides structural metadata
- Extend ESML schema by embedding semantic terms in the ESML Description File to provide a complete description of the data
- Allow various science communities can create their own ontologies (for example, SWEET) and use them with ESML Description Files for their data

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Example:
Embedding Semantics in ESML

```
<<a:ESML xmlns:a="ESML" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="ESML.xsd" >
 <SyntacticMetaData>
  <Binary>
   <Structure instances="1" name="SampleSet">
    <Array occurs="100">
     <Array occurs="100">
      <Field name="UWind" type="Int32" order="LittleEndian"/>
     </Array>
    </Array>
    <Array occurs="100">
     <Array occurs="100">
      <Field name="DimX" type="Int32" order="LittleEndian"/>
     </Array>
    </Array>
    <Array occurs="100">
     <Array occurs="100">
      <Field name="DimY" type="Int32" order="LittleEndian"/>
     </Array>
    </Array>
   </Structure>
  </Binary>
 </SyntacticMetaData>
</a:ESML>
```

Original ESML Description File containing only structural metadata

ESML Description File embedded with Semantic Tags defined in separate ontologies

```
<a:ESML xmlns:a="ESML" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="ESML"
xmlns:daml="http://www.daml.org/2001/03/daml+oil#"
xmlns="http://www.itsc.uah.edu/esml-ex#">
   <SemanticMetaData>
       <Latitude rdf:ID="DimX"/>
       <Longitude rdf:ID="DimY"/>
       <DataField rdf:ID="UWind"/>
       <DataSet rdf:ID="SampleSet">
           <hasField rdf:resource="#DimX"/>
           <hasField rdf:resource="#DimY"/>
           <hasField rdf:resource="#UWind"/>
       </DataSet>
   </SemanticMetaData>
   <SyntacticMetaData>
       <Binary>
           <Structure instances="1" name="SampleSet">

           </Structure>
       </Binary>
   </SyntacticMetaData>
</a:ESML>
```

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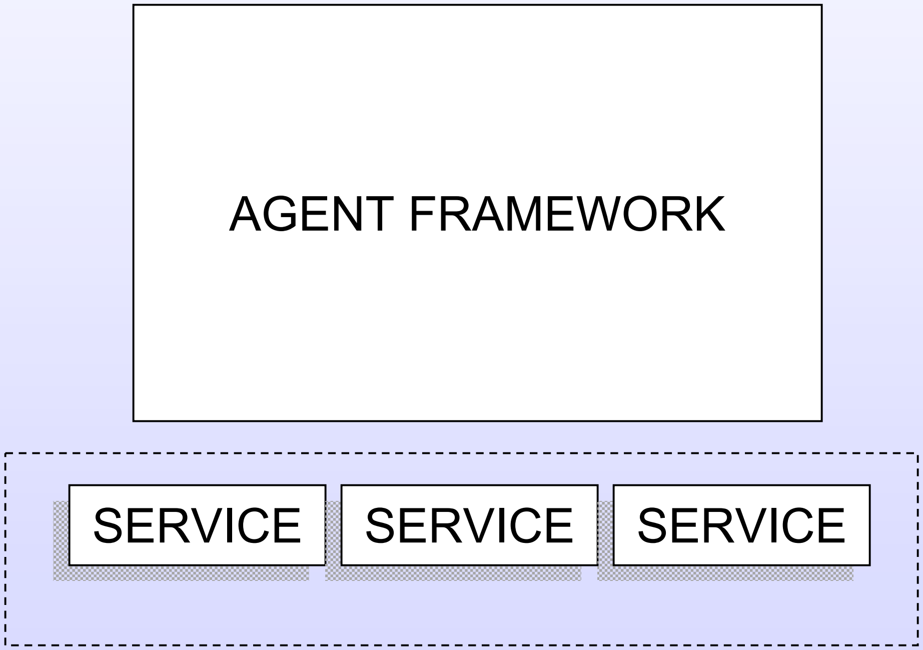
Agent Framework Design: Layer Architecture

- *Infrastructure Layer*: provides the environment that agents can act upon, i.e. services
- *Agent Layer*: contains the agents used to achieve the overall goal of the framework
- *Organization Layer*: defines the organizational structure of the system which is important for agents interaction
- *Coordination Layer*: defines coordination methods required to resolve conflicts and select the next agent
- *Constraint Layer*: verifies whether the system goals are met and interfaces with the users/user interface

Agent Framework Design: Infrastructure Layer

- Consists of "transcoding" services
  - Search
  - Subsetting
  - Data Format Translation
  - Calibration
  - Navigation
  - Reprojection
  - Visualization
  - Aggregation
  - Fusion
  - Mining



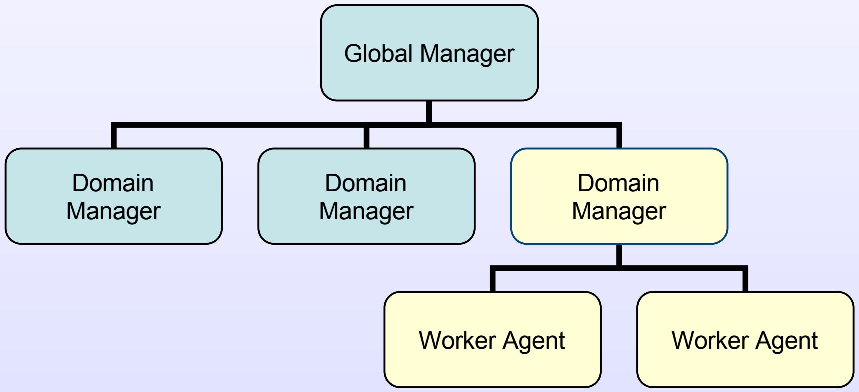
Agent Framework Design: Agent Layer (1)

- All the **agents** have the following features:
  - Role
  - Behavior- methods/functions that it can act upon
  - State – store information of itself and the world it perceives
  - Intelligence/Knowledge– to be able to make decisions via ontologies and a reasoning engine or via a machine learning algorithm or via heuristic algorithm
  - Communication protocol – to interact with other agents
- Types of Agents
  - Manager Agents
    - Global Manager
    - Domain Manager
  - Worker Agents

Agent Framework Design: Agent Layer (2)

- **Global Manager Agent:** Given an user input request, distribute the work and collate results
- **Domain Manager Agent:**
  - Keeps a registry of all the Worker agents in its domain
  - All Worker agents advertise their capabilities to the Manager Agent
  - Parses the incoming message and uses an ontology to find the “correct” Worker agent
  - Polls Worker agents for results
  - Fires and Hires Agents
- **Worker Agent**: Uses ESML semantic metadata and ontologies to **map** input message to API requirements of the Service
  - Example:
    - Navigate the data
    - Map Parameter Concept to Field Name(s)
    - Map Spatial Concept to Bounding Box
    - Map Temporal Concepts to Time Range

Agent Framework Design: Organization Layer



- A simple tree structure with a global manager and number of domains is used.
- Each of the domains contains a Manager agent and Worker agents
- Advantage: scalable design that will allow addition of new domains to the overall framework

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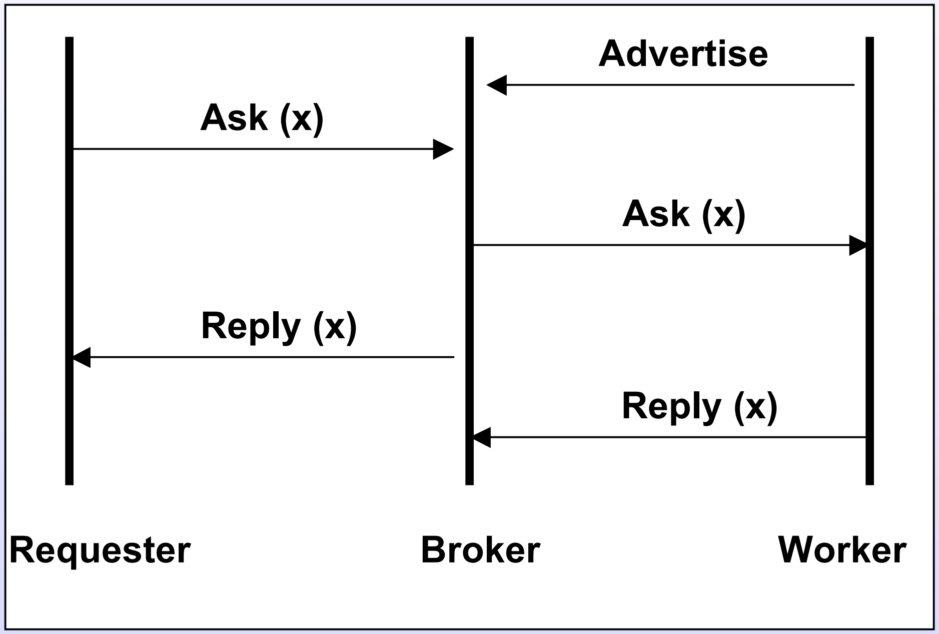
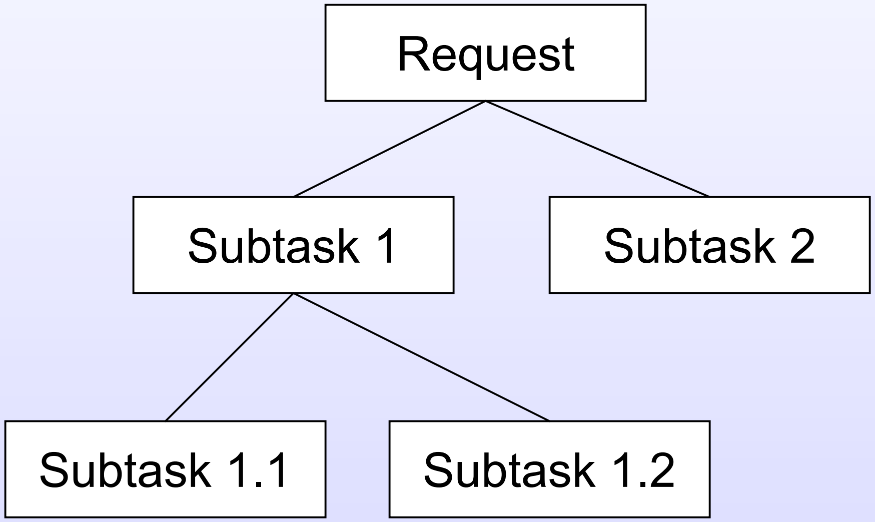
Agent Framework Design: Coordination Layer



- A broker model is used
- Advantage: unlike matchmaker or a contract-net, this model allows the broker to shoulder some responsibility of finding the right agent and returning the result

Agent Framework Design: Constraint Layer Design

- By using a tree to represents requests, one can check the goal achievement.
- When all the leaf and intermediary nodes are satisfied, resulting in completion of the root node, the task has been accomplished.

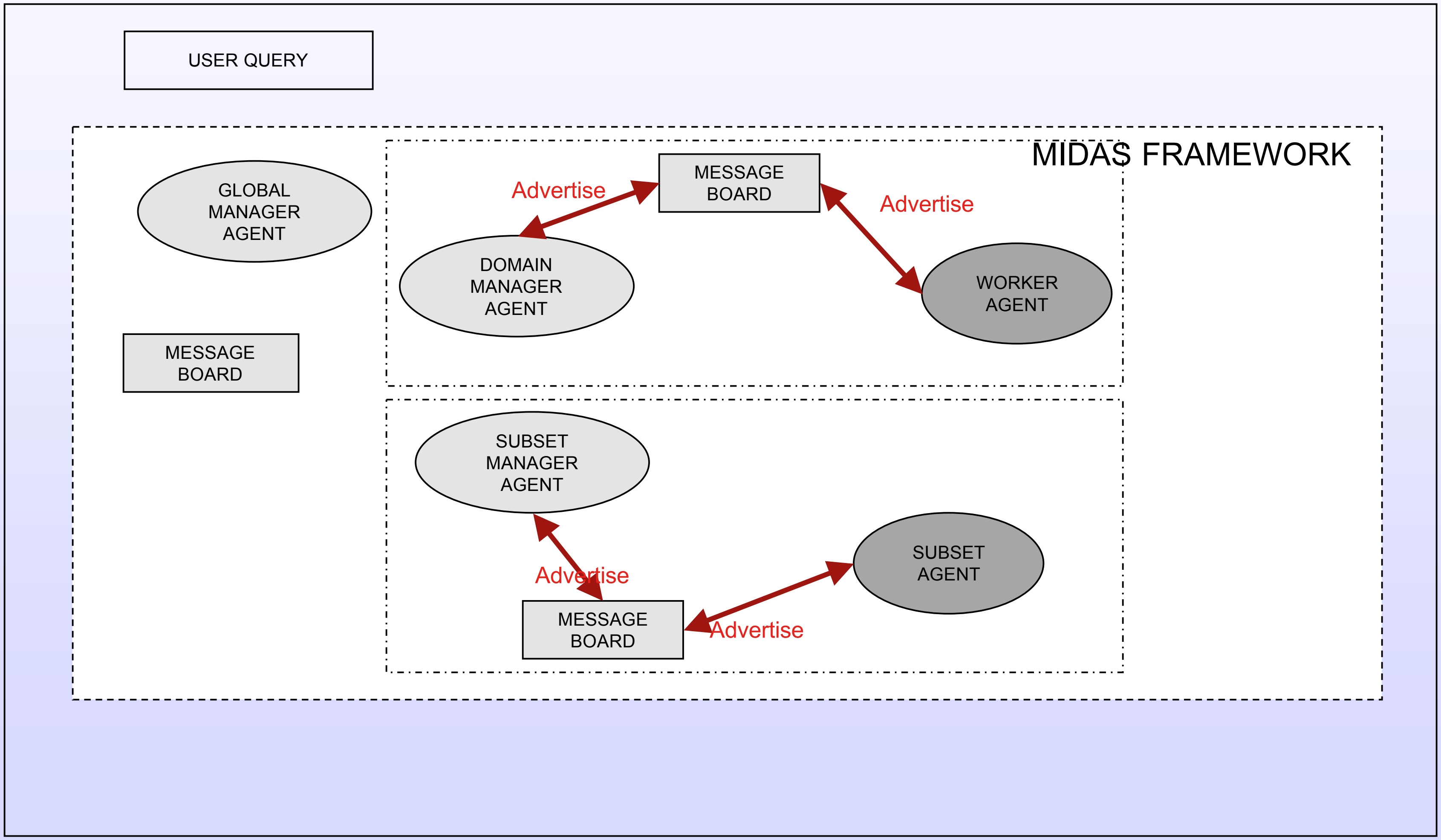


Agent Framework Design: Performatives

- Performatives are the permissible "speech acts" agents use to interact
- Partial set derived from KQML (Knowledge Query and Manipulation Language-UMBC)
- Basic Responses:
  - Error, Sorry
- Query:
  - Evaluate, AskStatus
- Capability:
  - Advertise

```
advertise
:content <performative>
:language KQML
:ontology <word>
:force <word>
:sender <word>
:receiver <word>
```

MIDAS in Action: Initialization



USER QUERY

MIDAS FRAMEWORK

GLOBAL MANAGER AGENT

MESSAGE BOARD

DOMAIN MANAGER AGENT

Advertise

MESSAGE BOARD

Advertise

WORKER AGENT

SUBSET MANAGER AGENT

Advertise

MESSAGE BOARD

Advertise

SUBSET AGENT

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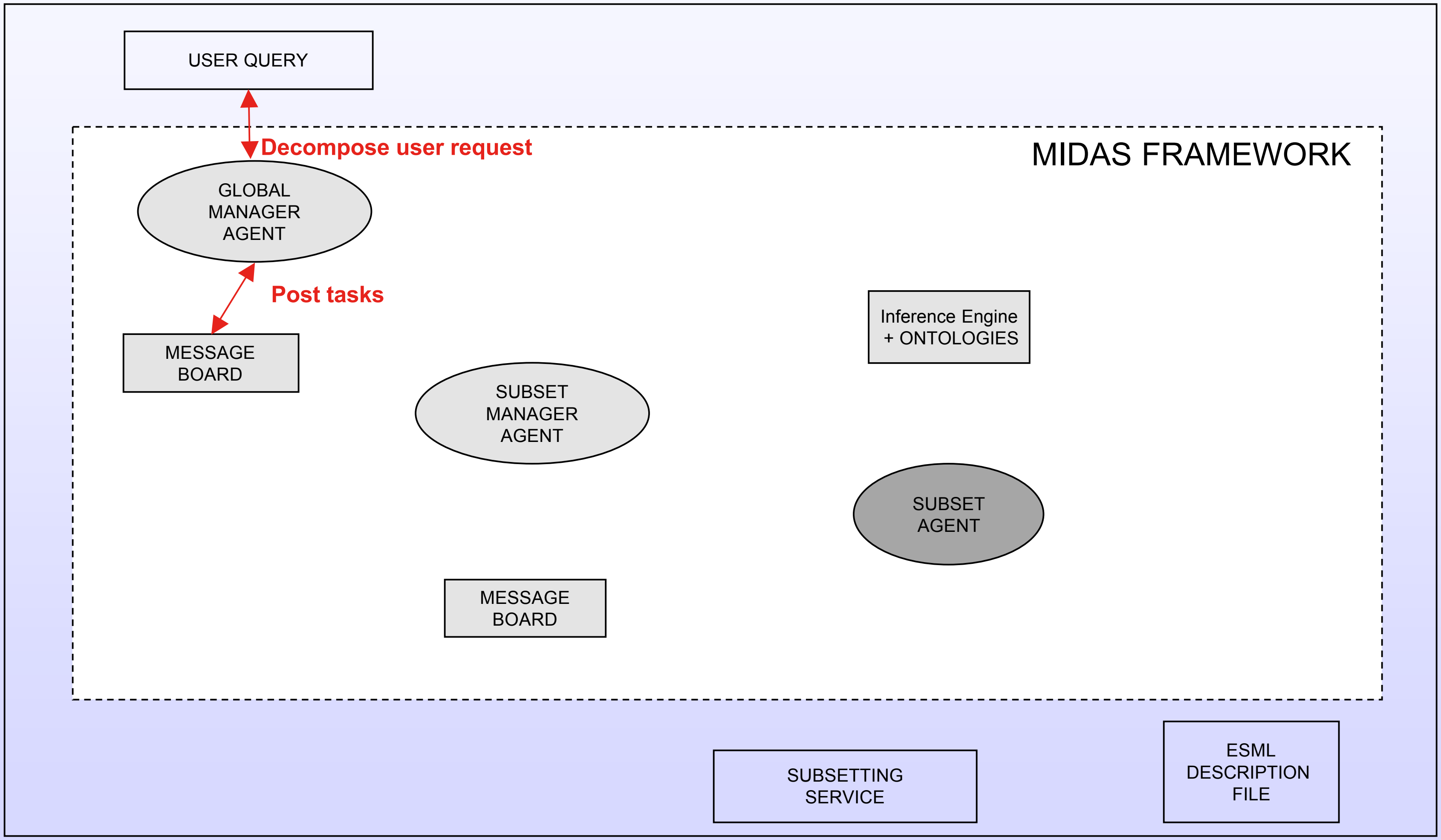
MIDAS in Action: Subset Query



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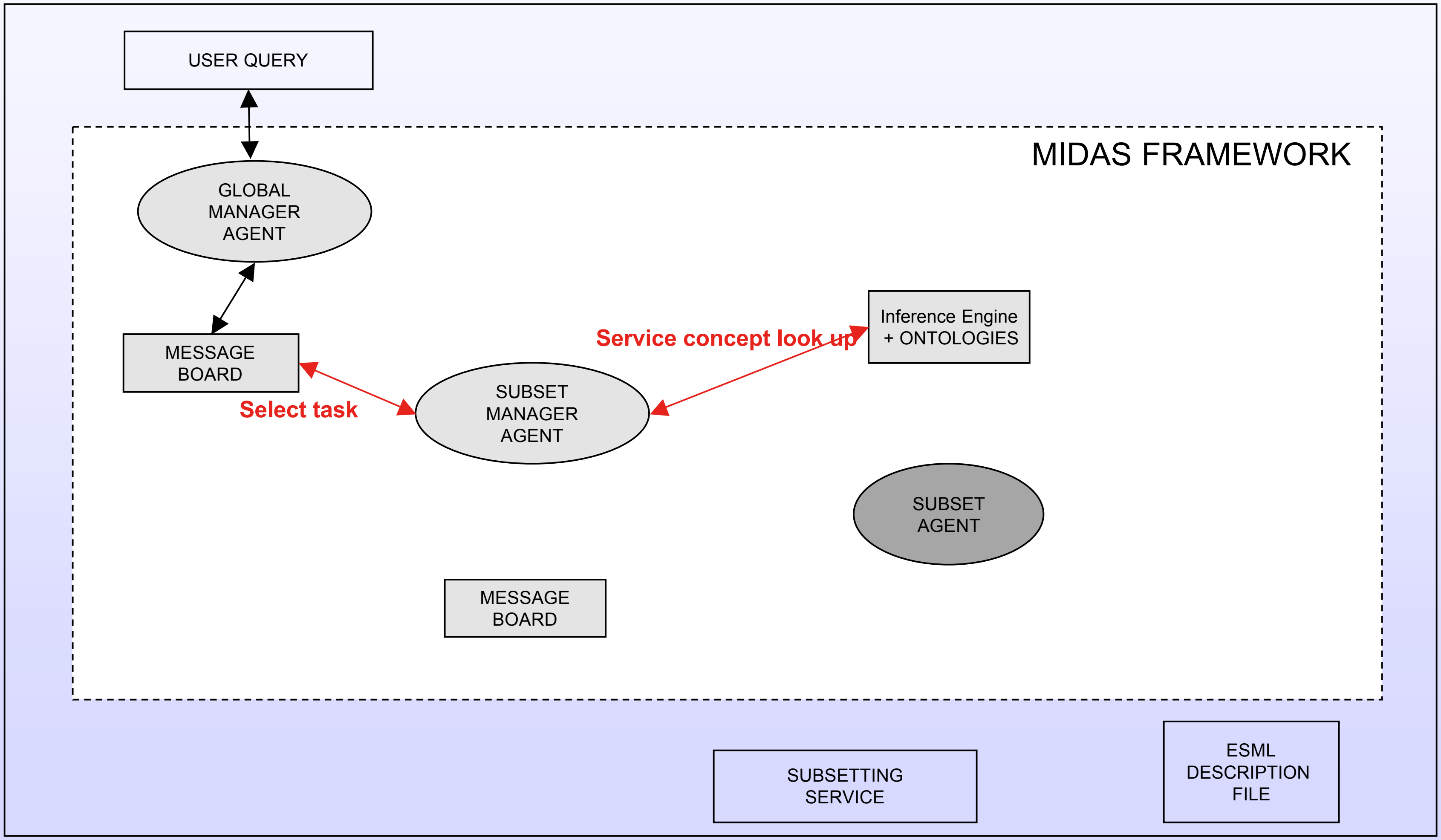
MIDAS in Action: Subset Query



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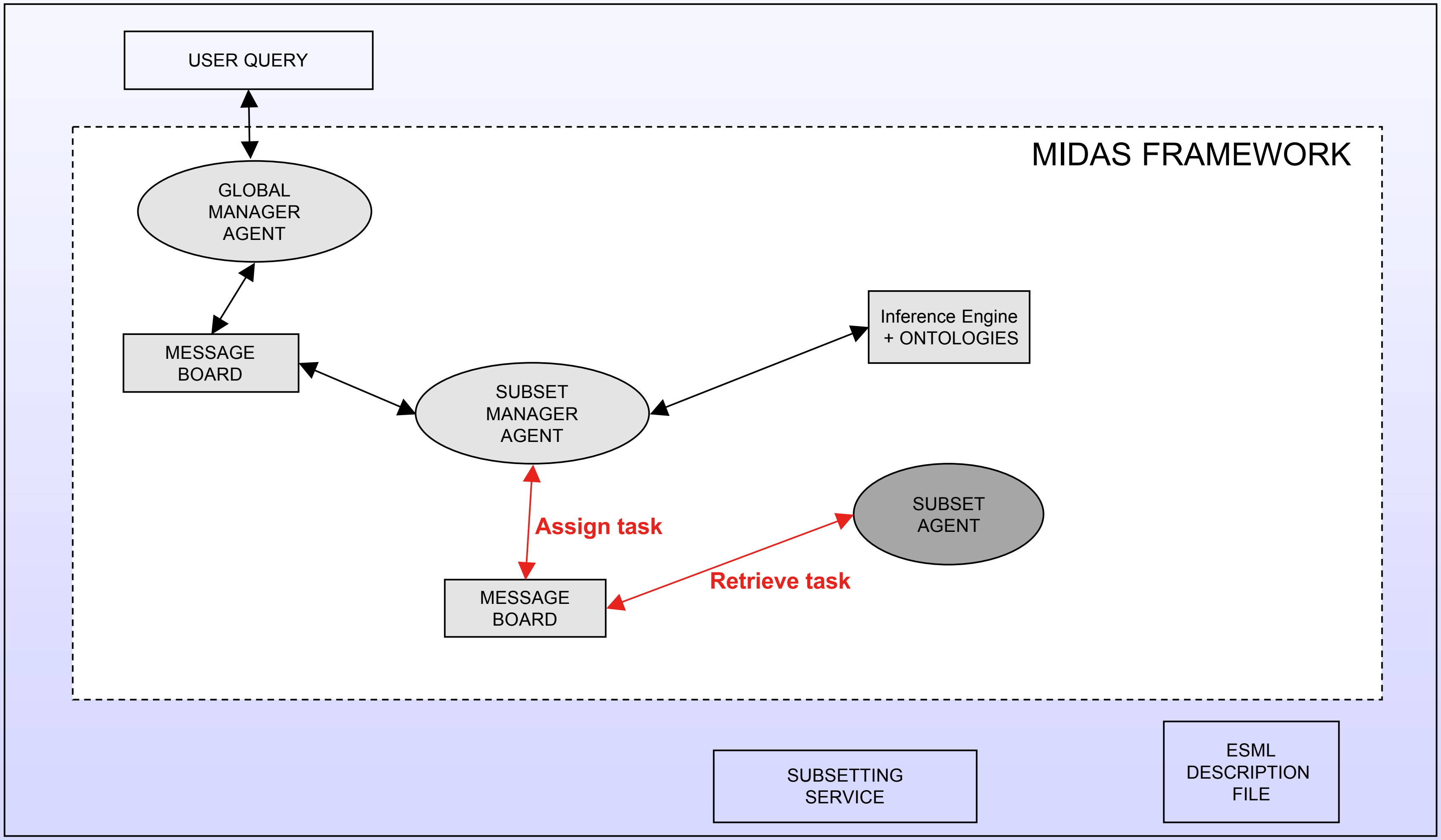
MIDAS in Action: Subset Query



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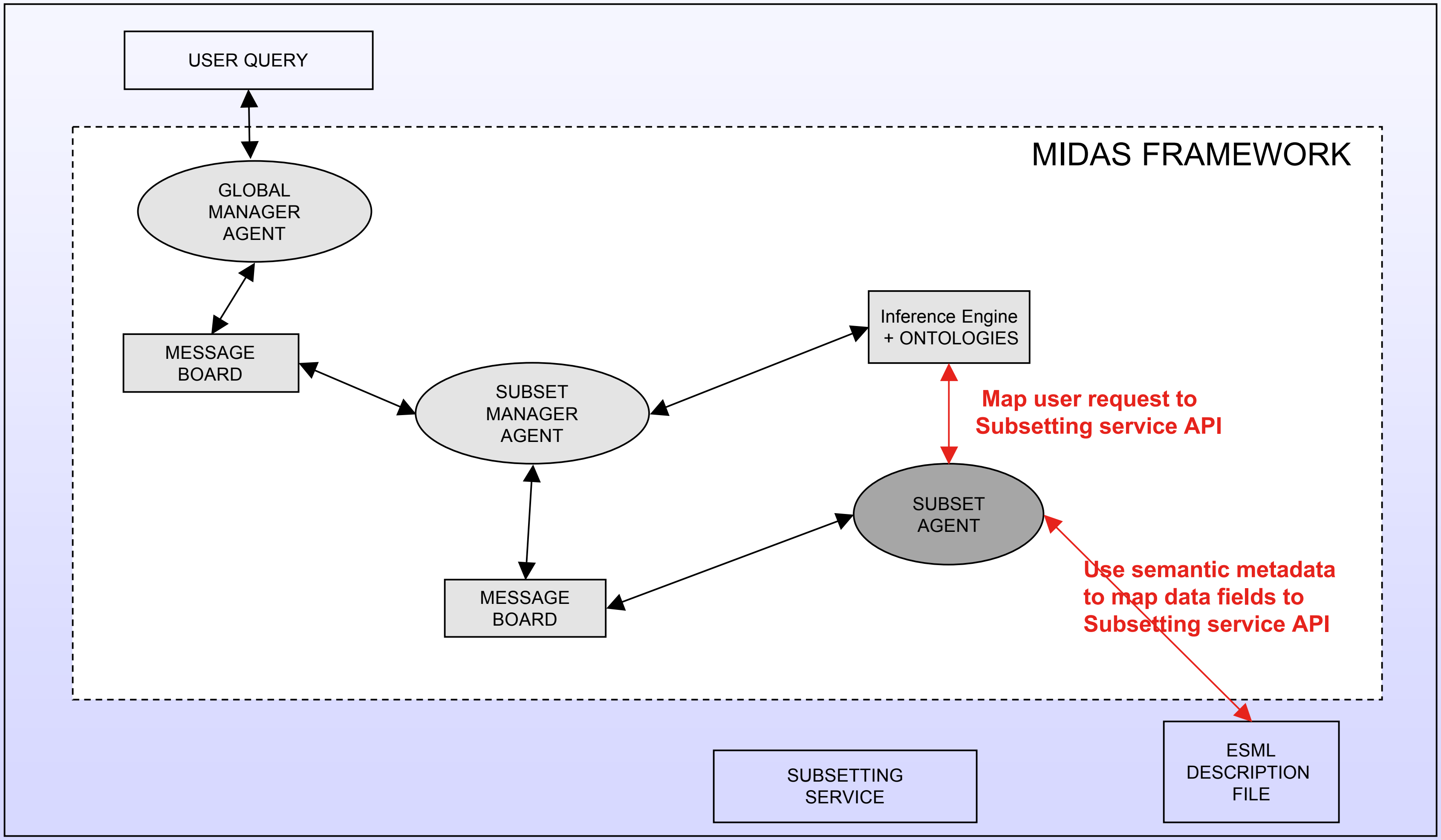
MIDAS in Action: Subset Query



Map user request to Subsetting service API

Use semantic metadata to map data fields to Subsetting service API

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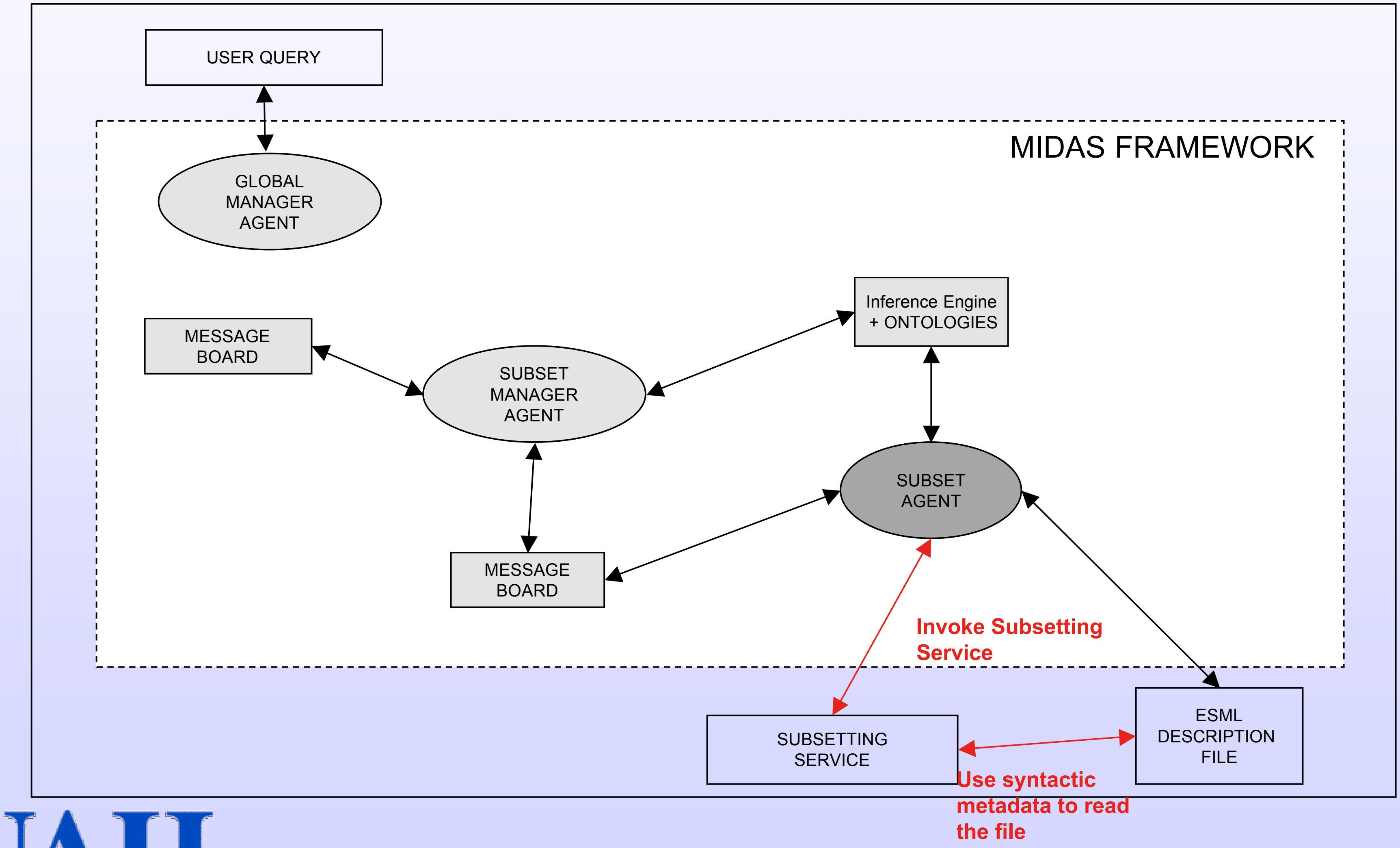
MIDAS in Action: Subset Query



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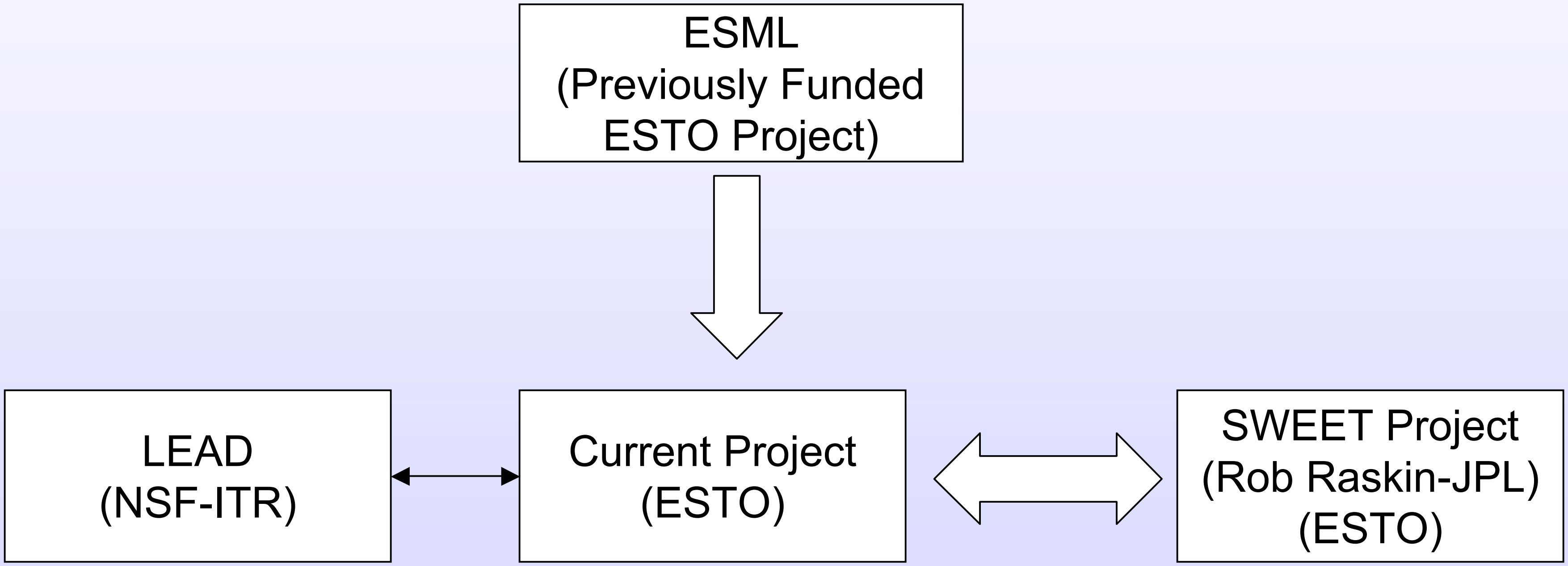
Demo: Simple Subsetting Query

- Given spatial and temporal bounds, subset a data file
  Domain manager selects a subset agent
  Subset agents performs the following actions:
  Navigate the data using ESML semantic metadata and the ontology
  Map the data to the subsetting service API

Publications/Presentations

- Ramachandran, R., H. Conover, S. Movva, and S. Graves, 2003: Using ESML in a Semantic Web Approach for Improved Earth Science Data Usability. *Semantic Web*, Sannibel, FL.
- Ramachandran, R., S. Movva, and S. Graves, 2003: Coupling Ontology with Earth Science Markup Language for Scientific Dataset Description. *Geological Society of America Meeting*, Seattle, WA.
- Movva, S., R. Ramachandran, X. Li, S. Khaire, K. Keiser, H. Conover, and S. Graves, Submitted 2004: Syntactic and Semantic Metadata Integration for Science Data Use. *Computers & Geosciences.*
- Ramachandran, R., S. Graves, S. Movva, and X. Li, 2004: Agent Framework for Intelligent Data Processing. *IEEE International Geoscience and Remote Sensing Symposium*, Anchorage, Alaska, IEEE.

Collaborations



ESML (Previously Funded ESTO Project)

LEAD (NSF-ITR)

Current Project (ESTO)

SWEET Project (Rob Raskin-JPL) (ESTO)

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Questions?